TECHNICAL REPORT 3072
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ADMINISTRATIVE INFORMATION

The work described in this report was performed for the Office of Naval Research (ONR) by the Radiation Technologies Branch (Code 56480) of the Maritime Systems Division (Code 56400), Space and Naval Warfare Systems Center Pacific (SSC Pacific), San Diego, CA.

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EXECUTIVE SUMMARY

A mechanism is introduced to model the phenomenon of spin in quantum mechanics. This model is motivated by an angle doubler mechanism used on an energy harvesting device. The authors used this mechanism to gain greater efficiency in their device. Analysis on this mechanism led to a connection with quantum mechanics. Quantum theory and quantum measurements show that a prepared sample with a particular spin does not return to its original spin state when the sample is rotated 360 degrees relative to the measuring probes. However, the sample will return to its original spin state only when the sample is rotated 720 degrees, or twice a complete rotation. This puzzling effect means that the spin states rotate ½ θ for a physical rotation of θ. We use the model to present an attempt to explain this effect using geometry. The model is extended by projective geometry, which provides a deeper understanding of electron spin. Surprisingly, the model led to a mechanism for spin generation from natural oscillations of the electron (Zitterbewegung). The model depends on both the existence of this high-frequency oscillation and the existence of a lag in physical space in following this high-frequency jitter. The model shows that the natural Zitterbewegung oscillation create a spin of constant helicity. The lag in physical space also warps space to generate mass. Both the spin moment and the mass predicted from the model are not exceeding different from the accepted values.

Other applications include a clearer picture of measurement theory, the application to the photon and the prediction of photon zero mass, and also provide a hint to the connection of this model with dark matter.

This paper shows that simple mechanical mechanisms can be used to help understand deep physics concepts and show the possibility that other simple concepts can be used to help understand other aspects of physics.

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1. INTRODUCTION

This report is not meant to show detailed mechanisms of quantum mechanics but rather to show the potential of using topology and geometry to explain aspects of quantum theory steeped in abstract mathematics. Quantum behavior has puzzled scientists ever since the development of quantum mechanics in the early 1900s. Examples of the puzzling behavior include (1) the ability of an electron to pass through both slits of a double slit apparatus, (2) the probabilistic behavior of the wave function, (3) the wave particle duality, (4) the apparent instantaneous connection between particles that are in entanglement, (5) the apparent collapse of the wave function when an observation is made, and (6) the observation that a prepared sample with a particular spin state returns to its original spin state only after two complete rotations of the sample. The last behavior defies common intuition on how things operate in the physical world. Yet, physicists have been using the half-angle formula for so long that this rather peculiar effect is treated as a routine result in their reports and calculations.

In 2013, the first author (J. Dea) was tasked to build an energy harvesting machine to extract energy from deep ocean currents. A tall cylinder pivoted at its bottom will rock back and forth when it encounters ocean current near the ocean bottom. This effect is due to vortice shedding near the cylinder surface. The rocking motion is used to turn the wheel of a pulley system. The pulley, in turn, moves magnets in and out of coils to generate electricity. The second author and project manager (W. Liu), suggested the use of an angle doubler mechanism to improve the length of the movements. Following this suggestion, an energy harvesting machine was built that used an angle doubler mechanism. While working on this energy harvesting machine it was determined that the angle doubler mechanism has the potential to model the half-angle spin effect.

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2. ANGLE DOUBLER MACHINE

The energy harvesting machine consists of a wheel with a pulley around it hanging two magnets that moves in and out of coils. An arm rotates the wheel, but in such a way that an angular rotation of the arm of angle θ results in a rotation of 2θ degrees in the wheel. Through this mechanism, the magnets are moved further and faster than they normally would have moved. Figure 1 shows a photo of the angle-doubler mechanism.

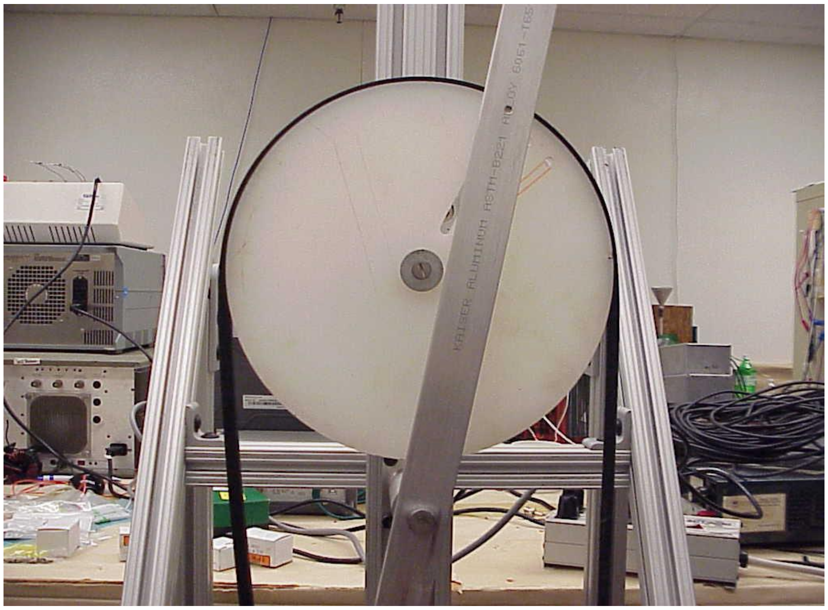

Figure 1. Photo of the angle doubler mechanism in the Space and Naval Warfare Systems Center Pacific (SSC Pacific) laboratory. Note the slot in the wheel. A pin rides along the slot and allows the wheel to rotate twice as fast as the arm.

Figure 2 shows a schematic drawing of the energy harvesting system that includes the angle doubler mechanism. This drawing shows the slot on the arm instead of on the wheel. This re-design allows for a greater degree of movement than having the slot on the wheel.

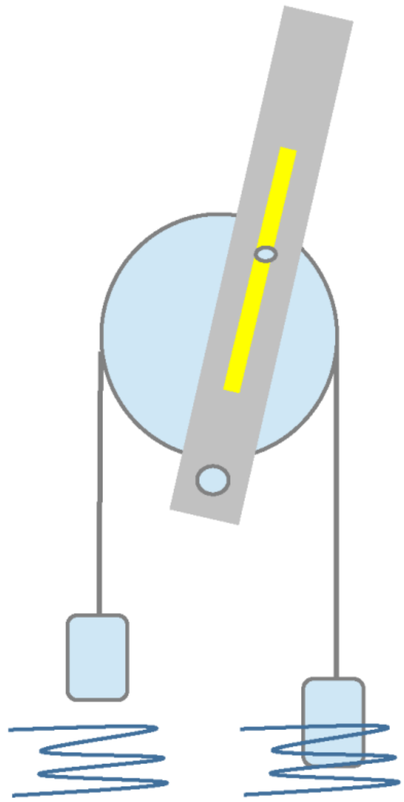

Figure 2. Pulley system lifting and lowering two magnets in and out of coils. A fixed pin near the rim of the wheel rides on a slot in the arm. The arm is pivoted near the bottom of the wheel. Angular motion of the wheel is double the angular motion of the arm, which is the basic angle doubler mechanism.

The actual machine also includes a large cylinder connected to the top end of the arm that rocks back and forth when it encounters ocean current. The rocking motion lifts and lowers the magnets in and out of coils to generate electricity. The machine was designed for rocking motion. If full rotation is desired, the arm and its slot need to be extended as shown in Figure 3a. A schematized version of the mechanism tracing the movement of the various parts of the mechanism is shown in Figure 3b.

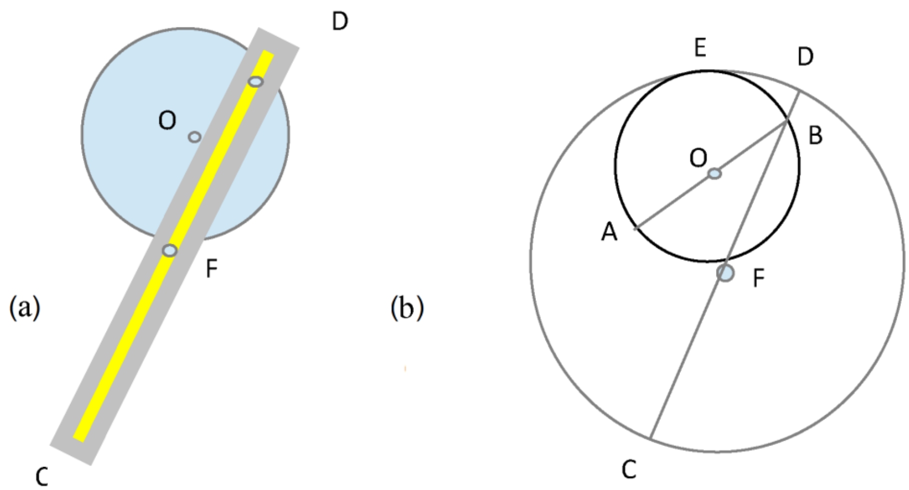

Figure 3. (a) Angle doubler mechanism for full rotations. (b) Schematized version. Cord AB rotates at double the angular speed of cord CD.

To clarify, cord AB represents the diameter of the wheel, cord CD represents the arm, point B represents the fixed pin on the edge of the wheel and rides on the slot on CD, point E is the point of intersection of the wheel with the larger wheel of the arm, point O is the center of the wheel, and point F is the center of the large wheel. Point F is also the pivot point of the arm. When cord CD is vertical, cord AB is also vertical, and points B, D, and E will all be at the same point. Figure 4 shows the example of a rotation of 90 degrees from the vertical for cord AB and a rotation of 45 degrees for cord CD.

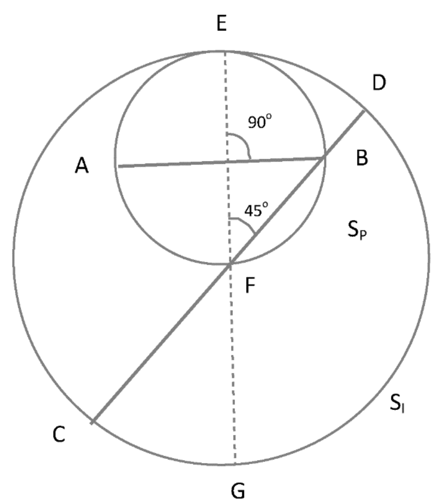

Figure 4. Cord AB rotated 90 degrees from the vertical, which corresponded to a rotation of 45 degrees for cord CD. S_P denotes physical space (small circle) and S_I denotes internal space (large circle). Dashed line, EG, is the projection screen.

The reader can easily imagine that when AB is rotated 180 degrees, then CD will have rotated 90 degrees. The projection of a spin along CD will be projected along the projection screen, EG. Extrapolating on this knowledge, it is clear that a rotation of 720 degrees of AB is needed in order for

CD to make a corresponding rotation of 360 degrees. If space, $S_{P,}$ is equated to physical space and if S_I is equated to internal space, then we can say that two full rotations of physical space are needed for internal space to return to its original state. Physical space is the 3D space in which normal objects reside. Internal space is a space with its own symmetry and has no extension in physical space.

3. SPIN FILTERS AND THE HALF-ANGLE EFFECT

There are only two electron spin states, either up or down. The up or down is of course for an impressed magnetic field imposed on the electrons to be measured. For example, if an electron is shot across a vertical magnetic field, its spin will either align with the field (spin up) or align in opposition to the field (spin down). We can prepare spin states using what are known as spin filters. The spin filter takes in a beam of particles, say electrons, and allows those electrons that are orientated as indicated on the filter (marked as an arrow on the filter) to pass. Consider a source of an electron beam, such as a heated electron emitter. In Figure 5, the source beam is passed through a spin filter in the up position. A second filter is placed after the first filter and a screen illuminates the electron beam.

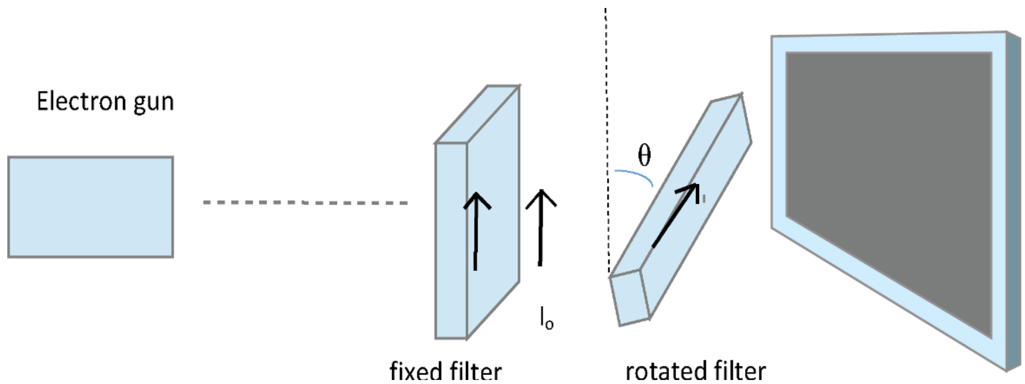

Figure 5. Spin filters preparing electrons for display on screen. The electron gun shoots a beam of electrons at the two filters and a screen. The intensity of the beam is I_o between the filters.

In Figure 5, the electron beam will be polarized spin up in the vertical direction, and the second filter will polarize the electrons spin up in the rotated direction. The intensity on the screen will be I_o*cosine^2(θ/2). If the spins are normal vectors, the intensity on the screen would be I_o*cosine^2(θ). The electron behavior is not that for a vector. For example, a vector polarized in the vertical has no projection in the horizontal. Yet, if the second filter is at 90^o , it is seen that 50% of the electrons are allowed to pass (spin up horizontal). The filter acts as if is at 45^o degrees. This shows that a rotation of physical space of θ corresponds to a rotation of θ/2 in spinor space. Following this rule, if the second filter is rotated 180^o , then the percentage of electrons allowed through is zero (cos(90^o)=0). In order for the projection of the spin to return to the original projection of 1 (at θ = 0), the second filter has to rotate 720^o degrees. The behavior of spin objects is counter-intuitive to common sense. In the physical world it is expected that any object returns to its original state when it is rotated 360^o degrees. However, when it comes to the spin system as shown in Figure 5, a physical rotation of 360^o does not return the system to its original state. A physical rotation of 360^o degrees corresponds to a spin value of -1/2. Only rotating 360^o degrees twice returns the system to its original state of 1/2. This unsettling state of affairs cannot be explained by invoking classical physics. Quantum mechanics has the mathematical tools to calculate the effect, though there is no qualitative explanation. Hopefully this model will present a model that can give an intuitive picture of the situation. It should be clarified that the values of the measured spin of a *single* electron can be either m = +1/2 or m = -1/2. On the other hand, the measurements of the spin filters work on an *ensemble* of electrons and there will be a gradual change in intensity on the screen as the second filter is rotated.

4. QUALITATIVE PICTURE OF SPIN OBJECTS

A semi-classical description of spin follows. A spin object with spin J (sometimes called the angular momentum) with magnitude $\sqrt{J(J+1)}$ has 2J + 1 states. When J is the intrinsic spin of the electron, it is denoted by S. The states of J are denoted by m. Thus, a spin ½ object has two states. They are m = +1/2 and m = -1/2, also called spin up and spin down, respectively. A spin one object has three states of +1, 0, and -1. A spin 3/2 object has four states of 3/2, 1/2, -1/2, and -3/2. A spin 2 object has five states of +2, 1, 0, -1, and -2.

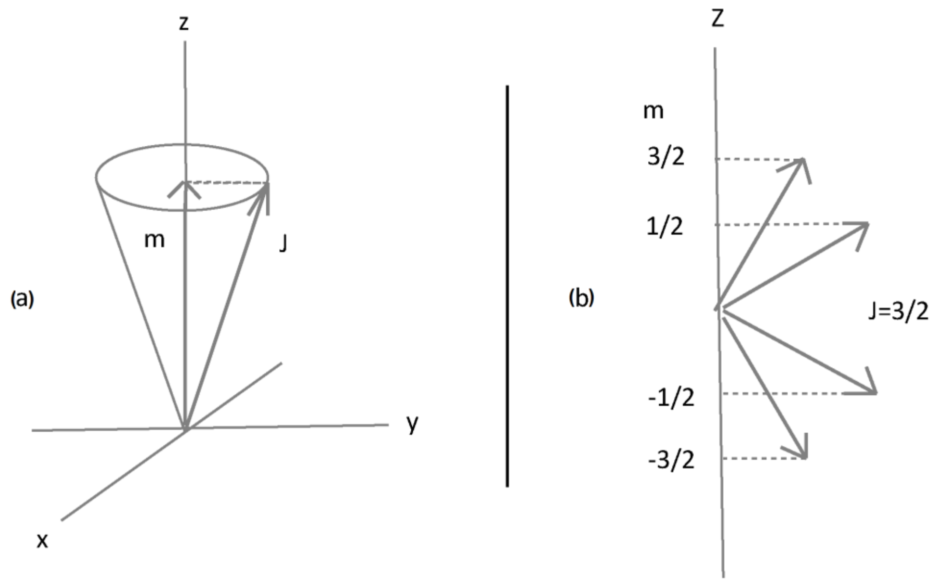

Figure 6. (a) Time average of J is m. (b) Example of the four states of J = 3/2.

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5. MODELING THE HALF-ANGLE EFFECT

A simple vector type model will be presented to produce the half-angle effect. This section refers to an ensemble of electrons rather than an individual electron, i.e., this section refers to a beam of electrons. The next section will explore the individual electron. In Figure 7, consider the line EG as the physical screen on which the spin is projected. Now consider that the line FB points in the direction of the spin. Thus, the spin of internal space points in the direction of FB but its projection on the screen in real space is through an angle, θ /2. The intensity on the physical screen will be $I\cos^2(\theta /2)$.

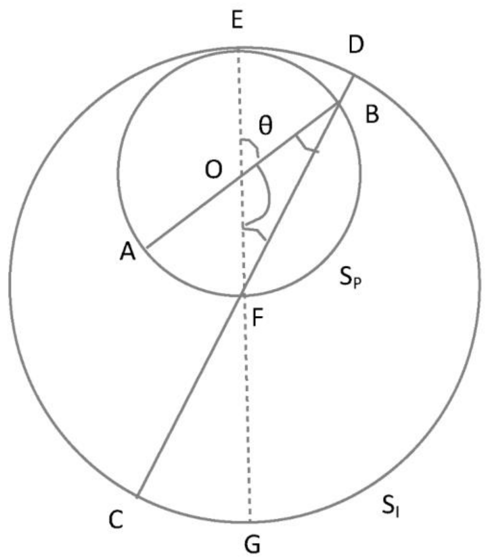

Figure 7. Modeling spin of an ensemble of electrons. The cord AB rotates θ from the vertical corresponds to a rotation of θ/2 for cord CD.

Hence, this simple exercise shows that a spinor can be viewed as a vector in internal space. A vector, V, in physical space with a tilt of θ with respect to the z-axis has a projection of $V\cos(\theta)$ on the screen. A spinor, on the other hand, acts like a vector that is tilted by θ/2.

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6. MODELING THE SPIN OF AN INDIVIDUAL ELECTRON

For an electron beam, the intensity of the beam in up-state is measured on the screen. For an individual electron, it is the probability of finding an electron in spin up that is measured. We will now model the dynamics of an individual electron.

Consider what happens when the angle EFD is greater than 90 degrees. Figure 8 shows what happens to the projection of spin pointed along FD when angle EFD is > 90 degrees.

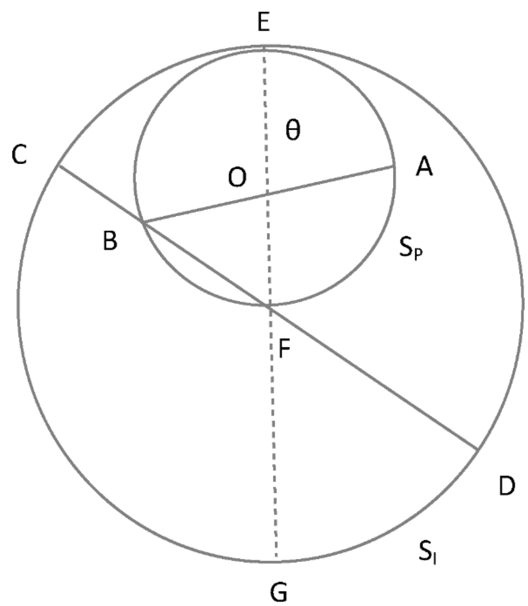

Figure 8. When angle EFD is > 90 degrees, the projection of the spin pointed along FD will be pointing down (along FG).

The projection of spin aligned with FD will be along FG (pointing down). Then the projection screen (FG) will seem to be outside of physical space. To rectify this inconsistency, we can project into a physical space that is a repeat of the original physical and denoted by the bottom circle in Figure 9.

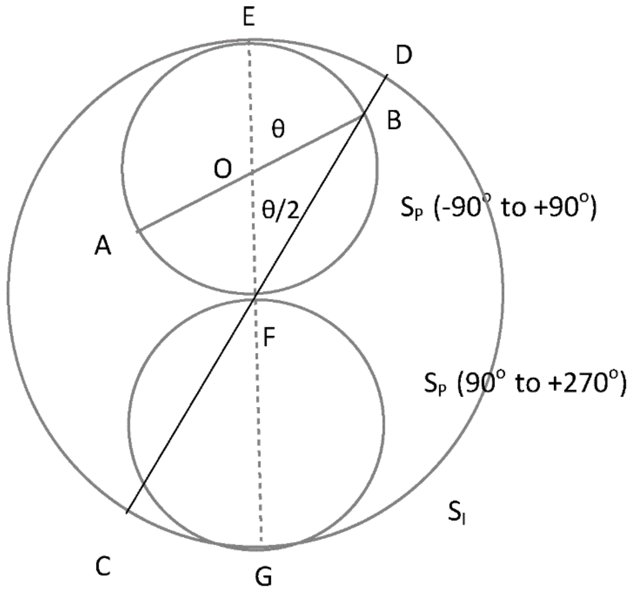

Figure 9. Basic model of geometry behind electron spin. The bottom circle is a repeat of physical space when rotation is from 90 to 270 degrees.

One of the key concepts of this report is that internal space dynamics is the primal driver while physical rotation is a response. Spin acts like an object from internal space, i.e., it returns to its original state only after a physical rotation of 720 degrees. According to Schrodinger (1940), there is an intrinsic high-frequency oscillation of the electron. The oscillation is named Zitterbewegung (German word for jitter). This jitter frequency is around 1.6 x 10^{21} radians/sec. This oscillation comes as a result of the beat frequency of the negative energy and positive energy solutions to the Dirac equation. The wave function and dynamics of the wave function of the Dirac equation occur in internal space.

7. MODELING ZITTERBEWEGUNG TO GENERATE SPIN

Because the spin of an electron returns to its original state only after a physical rotation of 720 degrees (or keep the electron spin fixed but rotate the measuring apparatus by 720 degrees), it is inferred that internal space, where the electron wave function resides, is more primal than physical space.

Consider a massless charge in high-frequency oscillation in internal space (the charge is just *e,* the charge of an electron). Physical space has attributes of permittivity, ε, which is a reactance to the electric field, and the permeability, μ, which is a reactance to magnetic field. In physical space the fastest motion is the speed of light, *c*, where $c = 1/\sqrt{\varepsilon\ \mu}$. On the other hand, we assume that internal space is not subjected to physical speed limitations. That is, superluminal speeds are allowed in internal space (this assumption is modified to an *appearance* of superluminal speed in section 11.2). We now make an assumption that the very high frequency Zitterbewegung oscillations in internal space cannot be followed in lock-step by physical space.

Figure 10 shows a counterclockwise jump of line CD (see arrow at D). The line AB, in physical space, cannot follow in step and lags CD. The new intercept is now X_1.

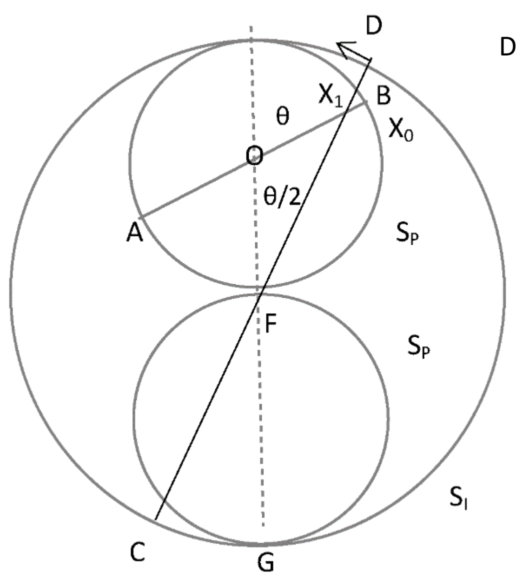

Figure 10. CD jumps in the direction of the arrow. CD intercepts AB at point X_1. The original intercept is denoted by X_0, which is also B.

Figure 11 shows the line AB lagging CD during 1/4 of the cycle. The new intercept is X_2.

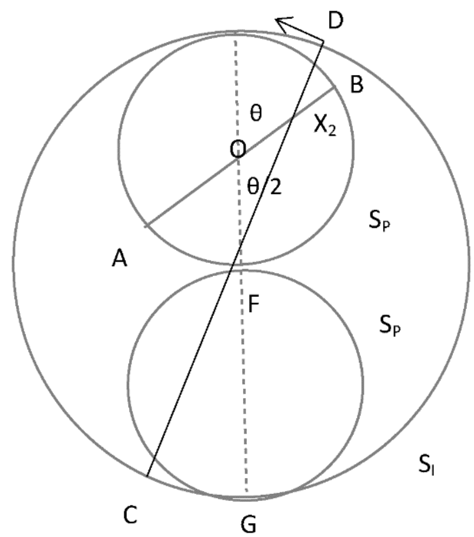

Figure 11. Delayed response by AB now intercepts CD at point X_2.

As CD slows down, line AB starts to catch up. Figure 12 shows new intercept at X_3.

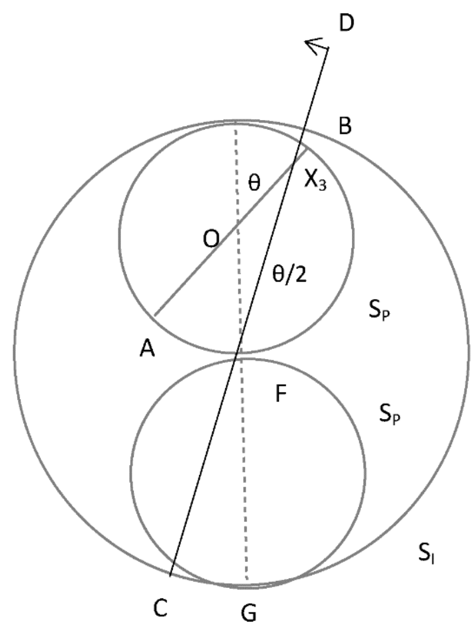

Figure 12. Line CD slows down its counterclockwise jump and line AB partially catches up. The interception is at point X_3.

Figure 13 shows the line CD jumping in a clock wise fashion and AB lags. The new intercept is at point X_4.

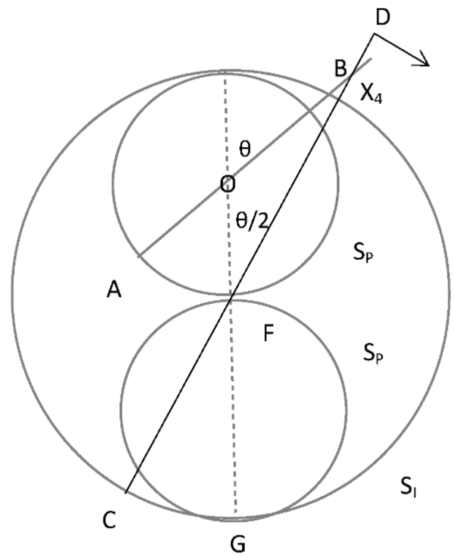

Figure 13. Cord CD jumps in a clockwise motion. The intercept is at point X_4.

If we plot the motion of X_1, X_2, X_3, and X_4, and then continue to plot X_5 and X_6, we find the clockwise pattern of Figure 13. In other words, a back and forth motion results in a one-way spin!

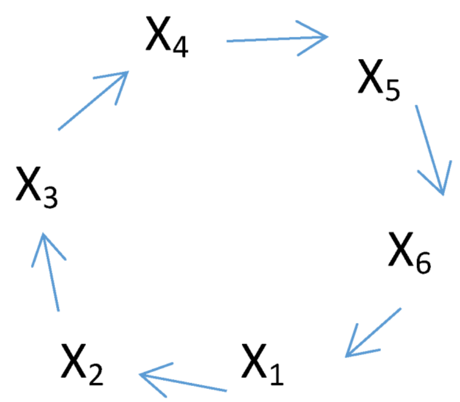

Figure 14. The overall motion of the oscillation of line CD (with pivot at F) results in a clockwise rotation (spin).

When the intercept of CD is on the lower circle, then the net motion is a counterclockwise spin. In general, symmetric operations such as oscillations about a fixed point result in symmetric reactions. However, we have shown that an angle-doubler mechanism with a delayed response generates a non-symmetric response. The response will be a spin of constant handiness (or helicity) despite the symmetry of the driving motion, which is an important result and shows the few instances in nature that a symmetric driving motion creates a one-way motion. In this instance, a back and forth motion creates a one-way rotation (a one-way ratchet).

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8. CALCULATING THE MAGNETIC MOMENT OF THE ELECTRON

So far, we have developed the concept of a massless electron of charge e undergoing clockwise (or counterclockwise) rotations (electron spin) at velocity *c* due to very high frequency oscillations in the primal object in internal space. Figure 15 shows the diagram of the dynamics.

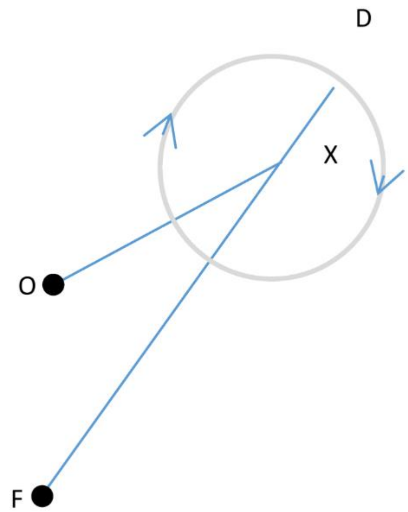

Figure 15. As FD oscillates about pivot F, the intersection with OX creates a spin.

The oscillation is at 1.6 x 10^{21} radians/sec or a frequency of 2.55x10^{20} Hz with a period of p = 3.92 x 10^{-21} sec. The circumference of the clockwise rotation is thus $c * p$ = 11.7 x 10^{-13} m. The radius and area is then easily calculated. The radius is 1.86 x 10^{-13} m, and the area is 1.09 x 0^{-25} m^2. Using e = 1.6 x 10^{-19} C, the current calculates easily from $I = f*e$ = 40.8 ampere. The spin magnetic moment for each loop can now be calculated from $\mu = I$*area = 4.45 x 10^{-24} amp-m^2. This result is about ½ that of the actual measured magnetic moment of the electron, 9.28 x 10^{-24} amp-m^2. The fact that this simple model predicts a value not exceedingly different from the measured value is encouraging.

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9. SIMPLIFICATION USING THE LANGUAGE OF PROJECTIVE GEOMETRY

To be less awkward, we can separate the up projections and down projections into two projections into physical space that would vector sum to a net spin (along with the appropriate scaling). Figure 16 is Figure 9 redrawn using only one circle.

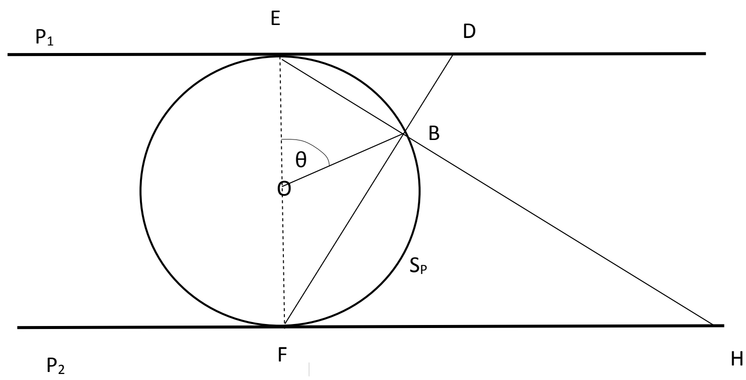

Figure 16. Condensed version of Figure 9. The projection screen, EF, now displays both positive and negative projections. The role of CD in Figure 8 is taken over by lines EH and FD. The lines EH and FD that intercept at the circumference of the circle are perpendicular to each other.

The projection of FB onto EF and the projection of EB onto EF, and their vector sum result in the net projection. When θ=90 degrees, the net projection is zero. The net projection is positive when θ < 90 degrees. The net projection is negative when θ > 90 degrees. Hence, it is seen that this one circle in Figure 16 replaces the positive and negative circles in Figure 9. In map making, the circle is actually a sphere, but we leave the circle as a plane for convenience. The lines P_1 and P_2 (in one dimensions as drawn, but are planes in three dimensions [3-D]) replace the large circle of Figure 8. We had converted Figure 9 into a double stereographic projection (Wikipedia, 2017, “Stereographic projection”), which is popular among cartographers. If this was a 3-D object (i.e., a sphere instead of a circle), tracing the outline of a continent on the surface of the sphere will then project that continent’s shape onto the planes, P_1 and P_2. The South Pole and its surroundings would be projected onto P_1 and the North Pole and its surroundings would be projected onto P_2.

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10. CONNECTION WITH MATHEMATICAL PHYSICS

Elie Cartan (1913) introduced a more general object than a vector. After realizing that his object is suitable for describing electronic spin, Cartan wrote a book that focused on the mathematics of spinors (Cartan, 1981). It is probably as much a chance discovery as it is a rigorous worked-out theory that Cartan's spinor object is built upon an isotropic vector (or a null vector) in complex 3 space. An isotropic vector is one where the complex vector (X_1, X_2, X_3) has a constrain that $X_1^2 + X_2^2 + X_3^2 = 0$. The components of this isotropic vector can be projected into complex 2 space represented by vector Z whose components are Z_1 and Z_2. Reference Wikipedia. 2017. "Spinors in Three Dimensions – Isotropic." shows that relation between the spinor components Z_1 and Z_2 and the complex 3 vector components are

$$Z_1 = \pm\sqrt{\frac{X_1 - iX_2}{2}} \qquad Z_2 = \pm\sqrt{\frac{-X_1 - iX_2}{2}} \tag{1}$$

The same reference also shows the inverse relationship (X_1, X_2, X_3) as a function of (Z_1, Z_2).

FD and EH of Figure 16 represent a simplified drawing of Z_1 and Z_2, respectively. OB represents (X_1, X_2, X_3). Rotation of the vector X by 720 degrees is equivalent to rotation of Z by 360 degrees and returns the system to its pre-rotated state.

These basic relations have been used to find quantum rotation operators. Without further elaboration, we list the rotation operators (reference UCSD 2013), which operate on the spinor part of the electron wave functions:

$$R_Z(\theta) = e^{i\frac{\theta}{2}\sigma_Z} \tag{2}$$

$$R_x(\theta) = e^{i\frac{\theta}{2}\sigma_X} \tag{3}$$

$$R_Y(\theta) = e^{i\frac{\theta}{2}\sigma_Y}, \tag{4}$$

where

$$\sigma_Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \qquad \sigma_X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \qquad \sigma_Y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \tag{5}$$

are the three Pauli matrices. Notice the half-angle dependence in Equation (2).

The isotropic vector and its zero length seemed reminiscent of a null interval in space-time physics. A null interval is where $ds^2 = -c^2dt^2 + dx_1^2 + dx_2^2 + dx_3^2 = 0$. It is then seen that $dx_1^2 + dx_2^2 + dx_3^2 = c^2dt^2$, and the spherical surface as a function of (dx_1 , dx_2, dx_3) is no longer static, but an expanding spherical surface that grows with time. According to Mcgrath (2015), if 2 waves with sources at point E and at point F of Figure 16 are considered, then the two expanding waves will create peaks and nulls that are pathways for energy flow. The energy flow in turn create structures that can be identified as elemental particles of nature. This type of holographic modeling is beyond the scope of the present paper.

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11. MASS GENERATION FROM SPACE DISTORTION

The existence of mass in fundamental particles is still a subject of mystery. The most current idea is that massless particles interact with a universal field, the Higgs field, and the interaction generates the equivalence of mass. The Higgs field bosons act like attractors to objects immersed in its field and force the objects to gain effective mass. Yet, perhaps there are other mechanisms for generating mass.

Compare point B in Figure 9 to point X_1 in Figure 10. Point B is located in physical space, here represented by a circle. The intersection of AB and FD lies on the circle (point B) when there is no lag. When there is lag, the intersection is at point X_1, which is not on the circle. In order for point X_1 to continue to reside in physical space, it is necessary for physical space to distort to accommodate the location of X_1. Figure 17a shows undistorted physical space and Figure 17b shows a possible distortion necessary to keep X_1 in physical space.

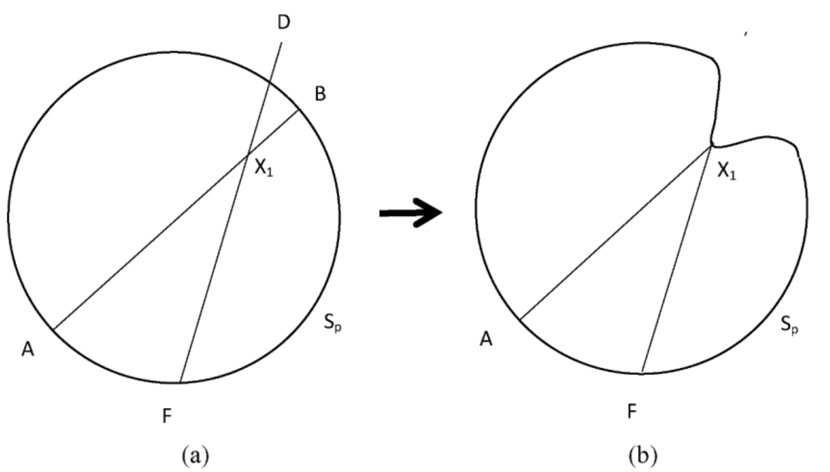

Figure 17. (a) Circle without distortion: (b) Circle distorted to allow point X_1 to reside in physical space, S_p.

The magnitude of the distortion in the figure is exaggerated in order for the reader to understand the concept. The distortion of physical space is perfectly aligned with the concept of warped space-time in general relativity. Warped space-time results in gravitation force and parameterized by the mass parameter, m. Hence, our simple model introduces a mechanism to generate mass through the distortion of space.

To estimate the mass generated from this distortion, one can assume that all the energy of the massless charge oscillating at the Zitterbewegung frequency is converted to the potential energy of space distortion. Normally, a charge oscillating at high frequency will emit radiation. But here the energy of the oscillation is converted to space distortion. As in general relativity, space is endowed with a spring like quality. Set mass energy equal to ground state oscillating energy of the vacuum (zero point energy).

$$mc^2 = \frac{1}{2}hf \tag{6}$$

Using h = 6.6256 x 10^{-34}J s, and f = 2.55 x 10^{20} Hz, we obtain that m = 9.4 x 10^{-31} kg.

This value for the electron mass is about 3% larger than the actual measured value. Again, the model predicts a quantity not exceeding different from the measured value.

It is postulated that other fundamental particles also have their masses generated by the space (or more generally space-time) distortion mechanism.

If we view a point of space as a spring, then the spring constant of a space can be estimated by setting the spring potential energy equal to the mass energy:

$$\frac{1}{2}kx^2 = mc^2 \tag{7}$$

Using m = 9.4 x 10^{-31} kg, period = 3.92 x 10^{-21} sec, and x = ½ c*period results in k = 4.9 x 10^{11} Nt/m. A typical 2-cm long steel spring with a diameter of 1 cm has k ~ 500 Nt/m. Thus, space is roughly 1 billion times as stiff as a typical spring. “Stiff” is usually referred to Young’s modulus, but we apply the definition more loosely and include springs in its context. Notice in this spring model of space, the mass is proportional to the square of space deviation, x. Thus, whether x is positive or negative, a positive mass is still the result.

11.1 EXPERIMENTAL SUPPORT FOR THE LAG EFFECT

Surprisingly, a search through the literature to find any validation of this model found a recent report (Zyga, 2014) that the onset effective mass depends on the speed of a disturbance impulse. An earlier paper (Chang et al., 2014) showed the same phenomenon. According to the report, it is well known that the effective mass of a particle depends on the environment. For example, electrons in the environment of GaAs lattice, has an effective mass of 0.067 of the electron bare mass, but electrons in the environment of Si lattice has an effective mass of 1.06 that of the bare mass. The main idea of the report is that if the disturbance pulse is fast enough, the environmental influence lags and the electron acts like a free electron despite the environment. We present a similar idea in this report: The very high frequency Zitterbewegung oscillations cannot be followed in lock step and a lag exists in physical space with respect to internal space. The lag drags physical space generating both spin and effective mass.

11.2 THE LAG MECHANISM

A previous section makes the assumption that superluminal velocities are allowed in internal space. However, most physicists are not so forgiving. They will insist on a velocity limit of c in all frames of reference. To allay the distrust in superluminal propagation, we will show that superluminal propagation can be an effect rather than a direct propagation from point A to point B. Consider a more detailed look at the double stereographic projection.

Figure 18 shows two single photon flashlights at point E and two more single photon flashlights at point F. The flashlights are synchronized such that photons from E will strike photons from F at the points B_1 and B_2.The figure shows the example of instantaneous propagation from B_1 to B_2 when $t_2 - t_1$ is set equal to $(d_1 - d_2)/c$. If $t_2 - t_1$ is set to equal to $(d_1 - d_2)/c$ + arc $(B_1 B_2)/c$ then B_1 will appear to move to B_2 with a velocity of c. Thus, the condition $(d_1 - d_2)/c < t_2 - t_1 < (d_1 - d_2)/c$ + arc $(B_1 B_2)/c$ will give the appearance that B_1 is propagating to B_2 at a velocity faster than c. But B_1 is an actual coupling to physical space and must move to B_2 at velocity c or less. If the internal space motion is to cause faster than c propagation, then there has to be a lag in physical space.

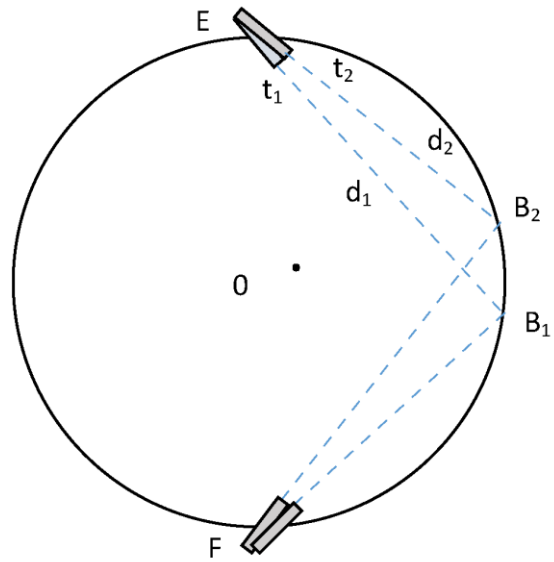

Figure 18. A photon is shot from E at t_1, travels d_1 and reaches B_1. A second photon is shot at time, t_2, travel, d_2, and reaches B_2. If $t_2 – t_1$ is set equal to the time, $(d_1 – d_2)/c$, then the point, B_1, will appear to move to B_2 instantaneously.

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12. CONCEPT OF NATURAL COUPLING

This report introduces the concept of natural coupling between physical space and internal space. Consider Figure 4, where cord AB is the diameter of physical space and cord CD is the diameter of internal space. The intersection and coupling of the two spaces occur at point B. In physical space, point B displays the dipole moment of the spin that interacts normally with any electromagnetic field in 3-D physical space. On the other hand, in internal space, point B is where the spinor object resides, which gives rise to the spin properties (such as the half-angle rotation that has no analog in 3-D space). We can call this the Coupling Already There (CAT) concept. One can say that the spinor object directly and naturally couples to the spin magnetic moment in physical space.

On the other hand, consider the extent that the physicist went to find a way to create a mass generating field to couple to a massless particle. Some background is necessary. Electromagnetism is very successfully described by a four-component gauge field, F, with U(1) symmetry. (U(1) is unitary symmetry with one parameter). Testing any gauge field with a change in gauge (same as change in phase) will induce a reaction from the field, which will show the properties of the field. The Lagrangian (related to the energy) of a gauge field will remain invariant with a gauge transformation. This statement is intuitively reasonable, since changing the phase of a field should not change its energy. However, the mass of the W and Z bosons in SU(2) theory depend on the choice of gauge (Wikipedia. 2017 “Higgs Boson”). Thus, W and Z particles must remain massless in theory.

In the 1950s, physicists applied the gauge field concept to particles, including electrons and protons, neutrons, and quarks. Higher order symmetries such as SU(2) and SU(3) were involved. SU(2) and SU(3) are special unitary symmetry with two and three parameters, respectively. By the end of the 1960s, a fairly rigorous unified foundation was laid using gauge field theories (known as the Standard Model). However, a sticking point with gauge field theories was that the particles have to remain massless to satisfy gauge invariance.

To go around the conundrum of a massless theory, physicists looked at ways that mass can be generated. One way is to add a scalar field (usually a four-component scalar field that forms a complex doublet) to the gauge field, which breaks the symmetry of the field to create mass but keeps gauge invariant of the gauge field intact (Wikipedia, 2017, “Higgs Boson”). The Lagrangian of the scalar terms will involve mixtures of the scalar field times the square of the gauge fields. Using dimensional analyzes, the coefficient of the squared field has dimension of mass (kg). Knowing this, physicist invoked a universal scalar field (the Higgs field) that interacts with all the elementary particles to generate mass. In order for this universal field to interact with the elementary particles, the elementary particles are endowed with a new charge, the electroweak charge. The universal field is given a coupling parameter, g, to the electroweak charge. An exchange particle, the Higgs boson, is invoked to exchange forces with the massless particles to give them mass. Thus, new universal fields, new charges, new coupling, and new exchange particles are invoked to generate mass for massless particles. The theories of the Higgs mechanism do not predict the mass of the Higgs boson. On July 4, 2012, a new particle with mass of 125 to 127 GeV/c was discovered from the CERN Large Hadron Collider (Wikipedia, 2017, “Higgs Boson”). The new particle has spin 0 and even parity and so was thought to the Higgs boson.

This report argues that the coupling between internal space and physical space is already there. It focuses on the rotation group, represented by Equations (2), (3) and (4). It is seen from these equations, that rotation in 3-D physical space is directly related to half-angle rotation in the internal space of Pauli matrices. We can also generalize to the weak and strong forces and claim that the internal space of isospin group, SU(2), is directly to related to its properties in physical space (e.g.,

nuclear decay), and that the internal space of color charge, SU(3), is directly related to its properties in physical space (e.g., quark distribution inside a proton). Thus, we claim that oscillations in internal space will directly couple to physical space and distort physical space, generating mass naturally. There is no need for exchange particles. Table 1 shows a comparison of the two mass generating mechanisms.

Table 1. Two types of mass generation in electrons.

Type	Coupling	Exchange Particle
Higgs	Electro-weak charge	Higgs Boson
Natural (this model)	Direct Coupling with Lag	Not necessary

Our model appears similar to space distortion as found in the theory of general relativity which is a classical theory. For now, a classical theory is a good starting point to further explore this concept.

13. OTHER APPLICATIONS

13.1 MEASUREMENT THEORY

Most of the diagrams in this report show a coupling between internal space and physical space at point B. However, we suggest that this situation happens only when an object of interest is being measured. When the object is not being measured it is in an undefined state. Following this approach, Figure 19 shows internal space in an undefined or unreferenced state with respect to physical space and the intersection point is not defined. One can infer that when internal space is not referenced to physical space, the natural buffeting by vacuum fluctuations will cause internal space to drift from alignment with physical space.

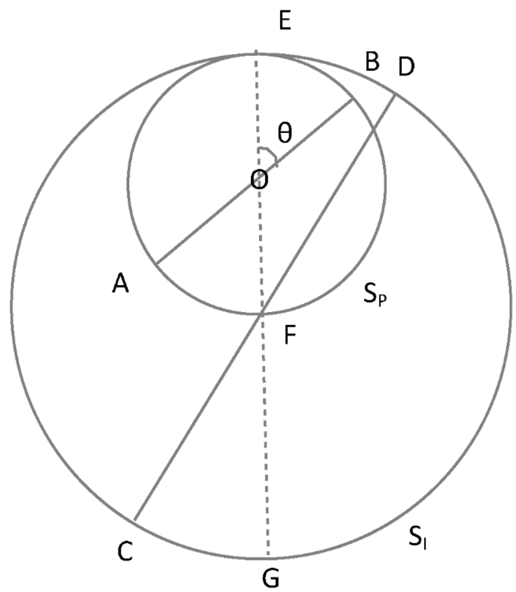

Figure 19. When a spinor object, CD, is not being measured, it drifts away from the intersection with vector AB due to natural buffeting by background noise.

Using a term from electrical engineering, we can say that internal space is “floating” with respect to physical space. Now, a measurement photon from the environment arrives at point B and its field reaches from B to X. The field causes a phase shift of the spinor wave function (represented by CD). A phase shift is equivalent to a rotation. The rotation aligns CD so that point X is at point B. In other words, the field from an external photon is an attractor that merges X and B. This process should not consume the photon. For example, using Equation (2), consider the spin part of the wave function to be pure spin up, $\psi_s = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$. A small rotation on this wave function gives a new wave function that is approximately $e^{i\frac{\theta}{2}}\psi_S$. Consider the energy consumed in this process. Using bra/ket notation, if the original energy is E = <E>, where E is an eigenvalue of the wave function, then E’ is the energy with the rotated wave function. The difference in energy is found in Equations 8 to 10.

$$\boldsymbol{E} = < \psi_s | E | \psi_s > \tag{8}$$

$$\boldsymbol{E}' = < \psi_s e^{-i\frac{\theta}{2}} | E | \psi_s e^{i\frac{\theta}{2}} > = \boldsymbol{E} \tag{9}$$

$$\boldsymbol{E}' - \boldsymbol{E} = 0 \tag{10}$$

Thus, according to Equation 10, the energy to rotate a floating internal space to be referenced to physical space is zero. This makes sense because it generally takes no energy to perform a phase shift. Hence, we provide a picture of countless billions of infrared photons from the environment that perform continuous measurements on an object and are not consumed in the process. Hence, observers see a stable objective world even though at the microscale, countless measurement processes take place every second. Standard measurement theory posits that the wave function collapses to a point during a measurement process. In our model, however, the wave function does not collapse. During a measurement process, the physical space and internal space align and allow the fields from internal space to leak into physical space through a point.

A brief comment on the phase shift mechanism is in order. It was known soon after the development of quantum theory that it is the more primal aspect of the electromagnetic fields, the potentials, that cause phase shifting of wave functions. These are the components of the four-vector potential (φ, A_x, A_y, A_z). Specifically, Aharonov and Bohm (1959) derived the relationships between phase shift and the integral of the potentials:

$$\Delta\theta = q/\bar{h} \oint \boldsymbol{A}\, dl \tag{11}$$

$$\Delta\theta = q/\bar{h} \int \varphi\, dt \tag{12}$$

Equation (11) shows that the phase shift is proportional to the path integral of the vector potential and Equation (12) shows that the phase shift is also proportional to the time integral of the scalar potential. A phase shift, $\Delta\theta$, that performs a rotation, $e^{-i\Delta\theta/2}$, consumes no photons, but allows an observer to observe objects in the physical world.

13.2 PHOTONS

This section concerns speculations on applying the model to the photon. It appears to work for photons. By analog with spin ½ , where the internal space is twice the size of physical space, the diagram for spin 1 photons can be drawn with internal space the same size as physical space.

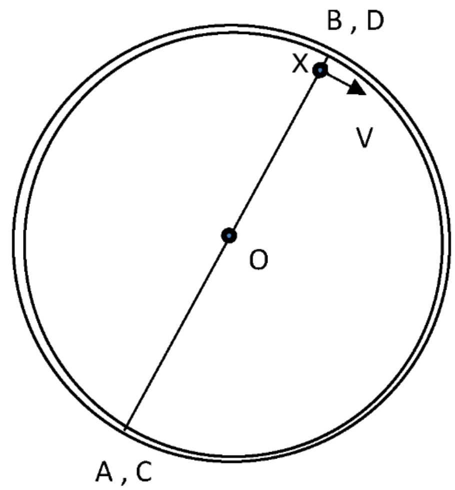

Figure 20. Internal space and physical space are drawn the same size for spin 1 photons. The connecting point between AB and CD is point X, which is also point B. A vector on X has a moment arm of V*OX.

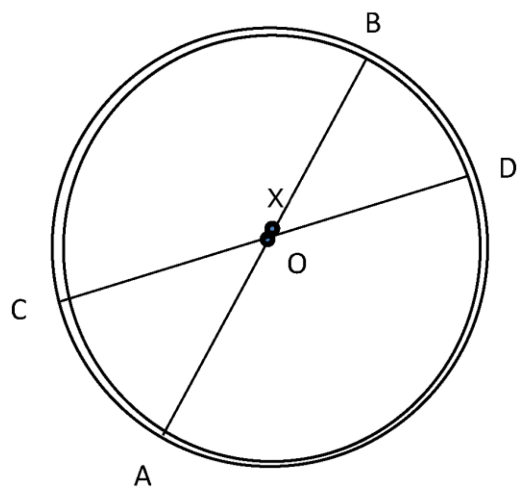

Figure 21. If CD drifts from AB, intersect X moves to the origin and the moment arm goes to zero. For this reason, it is believed that CD and AB are always aligned and move at the speed of light.

Consider a vector V, acting on point X in figure 20. The moment arm is V x OX. In figure 21, if CD and AB are not aligned, the intersection point goes to the origin, and the moment arm become 0. We speculate that AB and CD has to be connected at all times at point B, otherwise they cannot influence each other (no moment arm). The conundrum is how a connection can exist at all times. Perhaps this question can be answered if we relax the separate identities of internal space and physical space. Consider that physical space for a photon is a 3 dimensional vector space. Consider that the internal space of the photon is also a 3 dimensional vector space. Thus we can say that, for a photon, the internal space is the same as physical space. Thus, CD (the wave function in internal space) is always aligned with AB and there cannot be lagged between AB and CD. Since AB is the

wave function in physical space, the maximum speed is C. Hence we predict that the photon has velocity c, and has zero mass (no distortion of space).

The above discussion indicates that the wave function of the photon is in physical space. This means that the wave function is some linear combination of observable fields, E and H. For example one can set ψ_{photon} = aE+ibH. A technical analysis by Bialynicki-Birula (1994) of the photon wave function found that the photon wave function to be ψ_{photon} = aD+ibB which is the same equation since D=εE and B=μH. This is in sharp contrast to the wave function of an electron which is an abstract mathematical quantity devoid of any directly observable qualities.

13.3 DARK MATTER

High-frequency oscillation of a charged particle will result in electromagnetic radiation. However, in a bound state, such as electrons in an atom or quarks inside a proton, the oscillation will not radiate. The Zitterbewugung oscillations of an electron also do not radiate, which indicates that a bound state exists. We can also surmise that a chargeless particle oscillating and distorting space is a bound state between internal space and physical space. This bound state is suggested to be dark matter. When the oscillation exists purely in internal space, this suggests that this is dark energy. Table 2 lists known bound states and hypothesized bound states.

Table 2. Bound states known and suggested.

Type	Bound State	Kinetic Part	Kinetic Percentage of Mass
Atoms	Between electrons and protons	Moving electrons	0.0001%
Baryons	Between quarks	Moving quarks	Large but < 98%
Dark matter	Natural coupling between physical space and internal space	Motion of physical space	100%
Dark energy	Self-energy of internal space	Motion of internal space	N/A (pure energy, no local mass)

That dark matter and dark energy are included in this report shows the very general conceptions behind the natural coupling idea.

14. CONCLUSION

Speculation on the possibility of a simple angle-doubler mechanism to help explain electron spin led to an analysis of the situation. Mixing this speculation with theoretical physics concepts leads to a relatively simple model of electron spin. The model depends on both the existence of a high-frequency jitter (Zetterbewegung) and the existence of a lag from physical space in following this high-frequency jitter. The model shows that the natural jitter oscillations create a spin of constant helicity. The lag in physical space also warps space to generate mass. Both the spin moment and the mass estimated from the model are not exceeding different from the accepted values. That simple mechanical mechanisms can be used to help understand deep physics concepts shows the possibility that we can use other simple concepts to help understand other aspects of physics.

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14. ABSTRACT

This paper shows that simple mechanical mechanisms can be used to help understand deep physics concepts and show the possibility that other simple concepts can be used to help understand other aspects of physics. A mechanism is introduced to model the phenomenon of spin in quantum mechanics. This model is motivated by an angle doubler mechanism used on an energy harvesting device. The authors used this mechanism to gain greater efficiency in their device. Analysis on this mechanism led to a connection with quantum mechanics. Quantum theory and quantum measurements show that a prepared sample with a particular spin does not return to its original spin state when the sample is rotated 360 degrees relative to the measuring probes. However, the sample will return to its original spin state only when the sample is rotated 720 degrees, or twice a complete rotation. This puzzling effect means that the spin states rotate ½ θ for a physical rotation of θ. We use the model to present an attempt to explain this effect using geometry. The model is extended by projective geometry, which provides a deeper understanding of electron spin. Surprisingly, the model led to a mechanism for spin generation from natural oscillations of the electron (Zitterbewegung). The model depends on both the existence of this high-frequency oscillation and the existence of a lag in physical space in following this high-frequency jitter. The model shows that the natural Zitterbewegung oscillation creates a spin of constant helicity. The lag in physical space also warps space to generate mass. Both the spin moment and the mass predicted from the model are not exceeding different from the accepted values.

15. SUBJECT TERMS

angle doubler machine; spin filters; spin objects; spin state; half-angle effect; Zitterbewegung; projective geometry; quantum mechanics; quantum theory

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